Mars Molniya Orbit Atmospheric Resource Mining

Completed Technology Project (2016 - 2017)

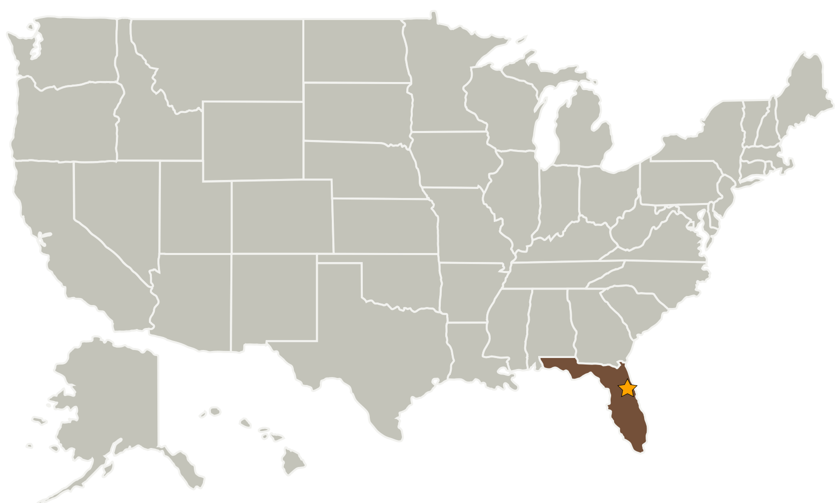
Project Introduction

Mars planetary surface access is one of NASA's biggest technical challenges involving advanced entry, descent, and landing (EDL) technologies and methods. This NASA Innovative Advanced Concept (NIAC) project intends to solve one of the top challenges for landing large payloads and humans on Mars by using advanced atmospheric In-Situ Resource Utilization (ISRU) methods that have never been tried or studied before. The proposed Mars Molniya Orbit Atmospheric Resource Mining concept mission architecture will make Mars travel routine and affordable for cargo and crew, therefore enabling the expansion of human civilization to Mars.

Anticipated Benefits

The proposed Mars Molniya Orbit Atmospheric Resource Mining concept mission architecture will make Mars travel routine and affordable for cargo and crew, therefore enabling the expansion of human civilization to Mars. This novel system, and associated concept of operations, offers a solution for large mass EDL (>18 t) using retro-propulsion methods with ISRU propellants made on orbit.

Primary U.S. Work Locations and Key Partners



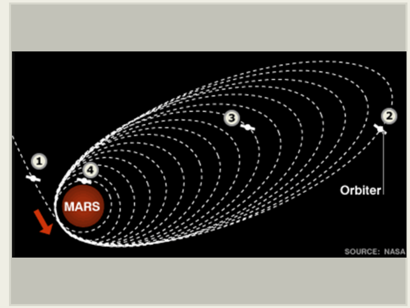


Image of Mars Molniya Orbit Resource Mining

Table of Contents

Organizations Performing Work	Role	Type	Location
★Kennedy Space Center(KSC)	Lead Organization	NASA Center	Kennedy Space Center, Florida
Georgia Institute of Technology-Main Campus(GA Tech)	Supporting Organization	Academia	Atlanta, Georgia

Primary U.S. Work Locations
Florida

Project Transitions

July 2016: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Kennedy Space Center (KSC)

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

Program Manager:

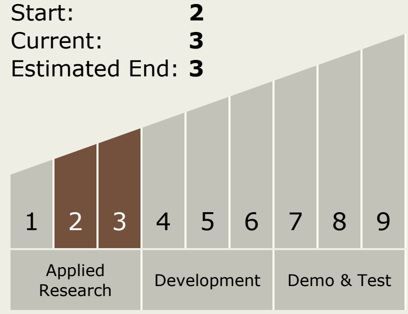
Eric A Eberly

Principal Investigator:

Robert P Mueller

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



June 2017: Closed out

Closeout Summary: This NASA Innovative Advanced Concepts (NIAC) Phase I study examined the revolutionary concept of performing resource collection and utilization during Mars orbital operations in order to enable the landing of large payloads. An exploration architecture was developed, out of which several missi on alternatives were developed. Concepts of operations were then developed for each mission alternative, followed by concepts for spacecraft systems, which we re traded to assess their feasibility. A novel architecture using Mars Molniya Orbi t Atmospheric Resource Mining is feasible to enable an Earth-independent and pi oneering, permanent human presence on Mars by providing a reusable, single-st age-to-orbit transportation system. This will allow cargo and crew to be routinel y delivered to and from Mars without transporting propellants from Earth. In Pha se I, our study explored how electrical energy could be harnessed from the kinet ic energy of the incoming spacecraft and then be used to produce the oxygen ne cessary for landing. This concept of operations is revolutionary in that its focus i s on using in situ resources in complementary and varied forms: the upper atmo sphere of Mars is used for aerocapture, which is followed by aerobraking, the kin etic energy of the spacecraft is transformed into usable electrical energy during aerobraking, and the atmospheric composition is the source of oxidizer for a lan ding under supersonic retropropulsion. This NASA Innovative Advanced Concept s (NIAC) Phase I study explores a novel mission architecture to establish routin e, Earth-independent transfer of large mass payloads between Earth and the Ma rs surface and back to Mars orbit. The first stage of routine mission operations i nvolves an atmospheric resource mining aerobraking campaign following aeroca pture into a highly elliptical Mars orbit. During each pass through the atmospher e, the vehicle ingests the atmosphere and stores it onboard, and then uses solid oxide electrolysis to convert the primarily CO2 atmosphere into usable O2 for pr opellant. Power is made available through the use of magnetohydrodynamic ene rgy generation, which converts the motion of the plasma in the shock layer into usable electrical energy. Upon termination of the aerobraking sequence, the des cent vehicle detaches from the orbit stack, deorbits, and executes the entry, des cent, and landing sequence. Hypersonic deceleration is achieved via a deployabl e heat shield to lower the vehicle ballistic coefficient, and supersonic and subson ic deceleration are achieved via retropropulsion. Mars surface operations involve resource mining of the Martian regolith to produce CH4 and O2 propellant to be used for the subsequent ascent of the Mars Descent Ascent Vehicle (MDAV) back to high Mars orbit (HMO) providing an apoapsis raise maneuver to initialize the aerobraking sequence, in addition to providing fuel from the Mars surface for the next Entry, Descent & Landing (EDL) propulsive descent, thus making the MDAV a reusable vehicle at Mars. The Resource Collector Vehicle (RCV), which is used for the orbital mining operations, is raised back to HMO via onboard deployable augmented solar electric propulsion. Concepts of operations were developed for each mission alternative, to evaluate between them and assess feasibility. In Ph ase I, we showed that for a human-class mission, with 81 orbital scooping passe s at 79 km altitude, with each atmospheric scoop varying in duration from 5.3 m inutes to 7.1 minutes, at speeds ranging from 3.57 km/s to 4.5 km/s, approxim ately 431 kg of CO2 can be ingested per scooping pass at periapsis and compres sed by a RCV with a hypersonic ram-compression system. The total amount of C O2 captured and stored is approximately 34,939 kg. Because of the SOE chemic al conversion process and other efficiency losses, this O2 product amounts to an estimated 20% of the captured CO2 mass - resulting in 6,986 kg of O2 for EDL propulsion to provide thrust for deorbit, reorientation for entry, supersonic retro -propulsion (SRP), and propulsive precision landing. A concept was developed, a

Technology Areas

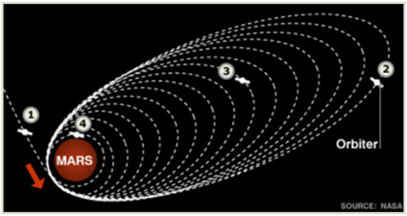
Primary:

- TX15 Flight Vehicle Systems
  - └ TX15.1 Aerosciences
    - └ TX15.1.7 Computational Fluid Dynamics (CFD) Technologies

Target Destination

Mars

Images



Project Image
Image of Mars Molniya Orbit Resource Mining
(https://techport.nasa.gov/image/102254)

Links

NASA.gov Feature Article
(https://www.nasa.gov/feature/mars-molniya-orbit-atmospheric-resource-mining)